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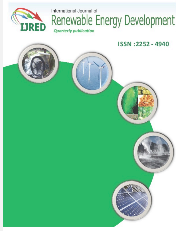

# Microgrids for rural schools: An energy-education accord to curb societal challenges for sustainable rural developments

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**ABSTRACT**. Quality education and schools have a key role to play in the sustainable development of society. Unfortunately, many remote communities in developing countries fail to enjoy access to quality education due to a lack of electricity, thereby interrupting regular school services in the villages. The main objective of the paper contributes to understanding the importance of the energy-education accord, and aims to curb the social challenges prevailing in the villages. Specifically, the paper suggests a technical intervention by designing a hybrid renewable energy system for such schools. The approach is demonstrated through a case study with a load demand of approximately 4 kWh/d, comprising a class size of 40 students. A techno-economic evaluation of the energy system reveals the levelized cost of energy of the system at USD 0.22 per kWh, which may be affordable considering number of other aspects, outlined in this paper, to enable a larger uptake of such systems in developing countries.

***Keywords:*** microgrids, rural electrification, rural school and education, techno-economic analysis, sustainable development goals

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## 1. Introduction

The United Nations Development Program (UNDP) aims for affordable and clean energy access (Aggarwal et al., 2014), and sustainable, decentralized systems have gained importance across the globe for the provision of access to electricity (Energy Information Administration, 2040; *IEA webstore. WEO-2017 Special Report: Energy Access Outlook*). Specifically, the decentralized systems have emerged as a leapfrogging approach over the decades for the provision of electricity to the remote locations of developing nations, where the access to centralized grid services are afflicted due to many challenges (Hiremath, Kumar, Balachandra, Ravindranath, & Raghunandan, 2009; van Gevelt et al., 2018). Moreover, other factors, governing a paradigm shift towards a renewed interest in decentralized systems, have been the result of improved and efficient performances of the power technology equipment paring with the appliance costs (Barman, Mahapatra, Palit, & Chaudhury, 2017; Bensch, Peters, & Sievert, 2017; Louie, 2016; Mentis et al., 2015; Rojas-Zerpa & Yusta, 2014). Also, higher installation and maintenance costs of the conventional transmission and distribution systems, with an inclination towards the notion of 'sustainable energy democracy', have resulted in growing interests towards small-scale energy systems (Burke & Stephens, 2017; Mandelli, Barbieri, Mereu, & Colombo, 2016), especially for those deprived of basic electricity access ("WEO 2018).

### *Literature review*

The scientific literature has addressed the issue with a focus on effective ways of energy source utilization techniques for small scale generations (Arto, Capellán-Pérez, Lago, Bueno, & Bermejo, 2016; Herington, van de Fliert, Smart, Greig, & Lant, 2017; Riva, Ahlborg, Hartvigsson, Pachauri, & Colombo, 2018). For instance, Rojas-Zerpa and Yusta examined the energy models, which can mathematically be utilized for rural electrification by introducing new paradigms for remote electricity evaluation criteria (Rojas-Zerpa & Yusta, 2014). Also, in the developing countries like India, Bangladesh and Malaysia, with a high prevalence of un-electrified villages (EIA, 2016; International Energy Agency (IEA), 2017), substantial efforts by the nodal renewable development agencies towards acquiring electricity for the rural despondent are evident (Palit and Chaurey, 2011; Taseska-Gjorgievska *et al.*, 2013; Saebi and Seyyed Mahdavi, 2018). For instance, projects like DESI Power and Gram Oorja in India, EDH in Haiti, and GE/T/P in Malaysia have been the driving examples of implemented microgrid projects using solar energy as the power generating source for electrifying the households (Shiroudi *et al.*, 2012; Sandwell *et al.*, 2016; Saebi and Seyyed Mahdavi, 2018).

Several methods are reported in the literature to highlight the importance of using hybrid renewable energy systems over the use of single-source systems for off-grid or island electrification (Chatterjee, Brent, & Rayudu, 2018; Chatterjee & Rayudu, 2017). Furthermore, many techno-economic studies are reported, which consider efficient optimization techniques for hybrid renewable energy sources to be utilized for the households, street lights and community health centers in off-grid communities and islands (Bhakta, Mukherjee, & Shaw, 2015; Diab & Ali, 2016; Jahangiri, Nematollahi, Sedaghat, & Saghafian, 2015; Mirzaei & Vahidi, 2015; Mohamed, Eltamaly, & Alolah, 2015; Saebi & Seyyed Mahdavi, 2018; Tijani, Wei Tan, & Bashir, 2014). A recent study emphasizes the identification of the rural typology with a mandatory storage system to be incorporated for designing a renewable energy system for rural electrification (Chatterjee, Burmester, Brent, & Rayudu, 2018). The author identifies the need for amendments to the technical standard IEC/TS 62257-2 to reduce the system complexity, thereby enabling an increase in the microgrid deployments for energy challenged villages.

Although the UNDP recognizes SDG.4 "quality education" as one of the 17 global goals that make up the 2030 Agenda for Sustainable Development, progress in education access has lacked behind, with 103 million youth worldwide lacking the basic proficiency in reading and understanding numbers (Pradhan, Costa, Rybski, Lucht, & Kropp, 2017). In addition, one in every four girls in a developing country have never been enrolled in a school (Jha et al., 2011; Li, Mattes, Stanley, McMurray, & Hertzman, 2009; Roy & Chattopadhyay, 2012). These situations are prominent in the remote locations of developing countries where a contrasting difference lies in the literacy rate of the urban and the rural dwellers (Chu, Wang, Xiao, & Zhang, 2017; Karakurum-Ozdemir, Kokkizil, & Uysal, 2018; Kararach et al., 2018; Lee, Low, Chong, & Sia, 2018). With a lower literacy rate in the villages, a dominant population lacks basic knowledge of energy management, sanitation, health care and wellbeing, in addition to increased inequalities and gender discrimination in the society. With a lack of health care knowledge and well-being, the employability scope reduces, adding to the poor economy and failure towards an integrated approach towards eradication of poverty. Thus all aspects of the SDGs are interconnected.

The statistics reveal that, in a developing country like India, the majority of the youth is in rural populations without basic education (Datta Gupta, Dubey, & Simonsen, 2018). The Government of India has subsequently started special programs and schemes for imparting compulsory education, such as "*Sarva Shiksha Abhiyan*" meaning "education for all" (Mir, 2018; A. Sharma & Bairwa, 2018; Yadav, Sharma, & Birua, 2018), and "Beti Bachao, Beti Padhao Yojana" meaning "save girl child and educate the girl child" (Saini & Sangwan, 2018; Verma, Dhaka, & Agrawal, 2018). Also, programs such as "midday meals" which is a complimentary program evolving with educational programs, aims at improving the nutritional standards of school children, can be seen as a step towards attracting the dwellers to schools and thereby progressing towards the achievement of the desired SDGs (Ayyub, 2018; Chakraborty & Jayaraman, 2019; T. Kumar, 2018; Power, Michalik, Couture-Nowak, Kent, & Mistlberger, 2018). Despite these efforts, the education in the rural villages of India has lagged behind, due to the lack of proper electrified primary schools, with prior research suggesting only 27 percent of village schools are electrified, compared to 76 percent of schools in urban regions (Ranjan, 2018). The lack of electricity infrastructure in the schools of remote communities often results in the students to use kerosene lanterns as an alternative (Aklin, Bayer, Harish, & Urpelainen, 2017; GNESD, 2014; Khandker, Barnes, & Samad, 2012; World Bank & Bank, 2008). Notwithstanding the ill-effects of the prolonged usage of kerosene lanterns, which lead to various lungs and respiratory issues, reduced eyed vision, and communicable diseases, such as tuberculosis, among the school students, the realization of the importance of electricity provision for education has been found to be scarce (Diniz, França, Câmara, Morais, & Vilhena, 2007).

### *The case of Lawjora*

A primary school at Lawjora, in the provincial state of Jharkhand, India, is considered as a case study for the research. The selection of the school is based on the fact that the presented research is the first in the state of Jharkhand, and a similar approach can solve the issues pertaining to a lack of electricity access for rural schools in the nearby villages, and similar developing country contexts. Also, the school is an exemplary scenario where a contrast in electricity access exists between the energy access in rural and urban areas considering the school is in proximity of 26 kilometers to the city Jamshedpur. The city is renowned for an iron and steel company and various other industries, and is the largest and the most developed city in the province of Jharkhand, with adequate facilities for a decent standard of living. However, the village remains in a state of poverty, primarily because it is separated by a river with a lack of infrastructure (K. Sharma, 2019; Walia, 2018). The provision of basic education and promoting social awareness among the residents of the village through education was identified as a necessary solution to the enduring village issues (A. Kumar, 2008).

A school in the village was subsequently established through the central-state government initiative as a part of the compulsory education scheme of the Government of India. The objective of the school was to diagnose the social issues and positively influence the youth. The school targeted the locals of the village to send their children for primary education in the age group of 6 to 14 years, with class sizes of approximately 40 combined age group students. However, interactions with the village children, and a senior representative of the village council, revealed a failure in the proper functioning of the village primary school stating the fundamental reason as an "*inappropriate environment of the classrooms due to a lack of electricity access in the school*". The absence of the electricity infrastructure has led to a lower retention period and attendance of the government teachers in the school for its proper functionality. Also, the non-conducive environment of the school classrooms presently attracts the children to visit the school for the midday meal only, rather than an interest in education and well-being.

### *Objectives of the paper*

The nearby villages experiencing similar circumstances, thereby urging the need for a technical approach to overcome the persisting socio-economic challenges of the villages in the province. The main objective of the paper is to propose a methodology to address the electricity challenges in the schools by demonstrating a sustainable hybrid microgrid system design, based on a lower levelized cost of energy that conforms to the affordability and the reliability attributes of the energy system for a school in remote locations. Furthermore, the research highlights key recommendations for further considerations, to disseminate the nexus for an electricity-education accord thereby strengthening the efforts in achieving the UNDP targets by the year 2030.

## 2. Research Methodology

For demonstrating the research strategy for electrifying a rural-based educational institution, a hybrid renewable energy system constituting of solar and the wind energy with battery storage has been designed for the remote primary school in the province of Jharkhand, India. The selected village, Lawjora, located in the East-Singhbhum district of Patamda block in the state of Jharkhand, India, is at an altitude of 129 meters above sea level. Fig. 1 and Fig. 2 illustrates the solar and the wind profile for the selected location as obtained from the global National Renewable Energy Laboratory (NREL) website considering the best practices for resource collection for renewable energy applications (Sengupta et al., 2015). The selected village typically receives the best daily solar irradiation (kWh/m2/d) in the month of April, followed by the lowest solar irradiation in the month of December. However, the average annual irradiance scaled for the location is 5 kWh/m$^2$/d, with a peak wind speed power of 15 hours and a scaled annual average wind speed of 2.6 m/s. The ample available renewable energy resources have thereby been considered for sustainable energy access for electricity to the school. The other corresponding factors, considered for effective utilization of wind turbines, constitute a Weibull distribution factor, a diurnal pattern strength and an auto-correction factor; of 2, 0.25 and 0.85 respectively.

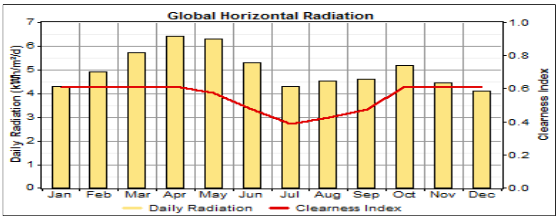

**Fig. 1** The solar profile for the selected location

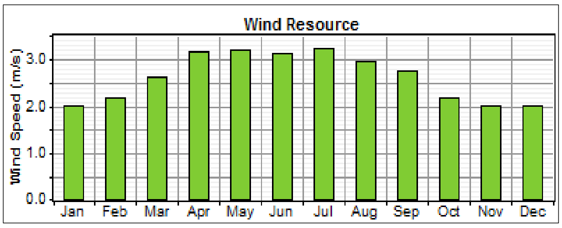

**Fig. 2** The wind profile for the selected location

### *Load Profile Estimation*

A load profile for the school was generated considering a systematic approach towards a similar usage of the electrical appliances over the year, with a varying seasonal load pattern demand and two seasons (summer and winter) have been considered for the site. The pivotal task of identifying the electrical appliances to be used by the school comprises of the compact fluorescent lamps (CFLs) for lighting, ceiling fans for cooling, a mobile charging unit, a desktop computer and television for promoting information and communications technology (ICT) activities in the school.

These appliance selection confirms the IEC/TS standard 62257, with Table 1 summarizing the electricity demand profile (EDP) for the primary school. A Hybrid Renewable Energy System (HRES) was then modelled for a primary school with a demand load of 4.3 kWh/d, a peak load of 1.1 kW, and a load factor of 0.16. The school had fixed working hours for its functionality, which was utilized to determine the number of appliances in a working state for every hour of a day generates a 24 hour load for two different seasons, as shown in shown in Fig. 3 and Fig. 4. For instance, the school starts at 8 am in the morning where the electric load constitutes the lighting and cooling load in the form of CFLs and ceiling fans during summer season. In addition to these, the desktop adds to the profile with variations in the mobile charging unit as when required. The school runs until 4 pm in the afternoon with an hour lunch from 12 pm to 1 pm. Also, the last hour of the school day constitutes an ICT session delivered via the desktop or television. The school runs until 4 pm in the afternoon with an hour lunch from 12 pm to 1 pm. Also, the last hour of the school day constitutes an ICT session delivered via the desktop or television. The administration work of the school is carried out till 5 pm hours, a lighting load is considered to be operating in the after-hours of the school as part of security measures to prevent theft and vandalism after which the school closes for the day. While the maximum electrical load is experienced during the school it is important to consider the absence of cooling load, in the form of ceiling fans in the winter season. With almost a definite electricity pattern usage, a random variability of 5 per cent with a time-step-to-time step variation of 10 per cent was considered for simulation of the microgrid system. An average annual load profile of the school is shown in Fig. 5. Based on the load profile generated, an HRES as shown in Fig. 6 was modelled, integrating a solar photovoltaic (PV) panel with a wind turbine as the main power generation units. A battery based storage system with the purpose of maintaining a quality power and reliability was considered in the model along with a converter.

**Table 1**
Electricity Demand Profile of the Primary School

| Electrical Load | Units of Appliances | Watts | Summer Season | | Winter Season | |
|---|---|---|---|---|---|---|
| | | | Hrs/d | Watt-Hrs/d | Hrs/d | Watt-Hrs/d |
| CFL | 10 | 20 | 9 | 1800 | 9 | 1800 |
| Ceiling Fan | 5 | 60 | 9 | 2700 | NIL | NIL |
| Desktop | 1 | 300 | 9 | 2700 | 9 | 2700 |
| Mobile Charger | 1 | 5 | 3 | 15 | 3 | 15 |
| Television | 1 | 60 | 1 | 60 | 1 | 60 |
| Total | | | | 7275 | | 4575 |

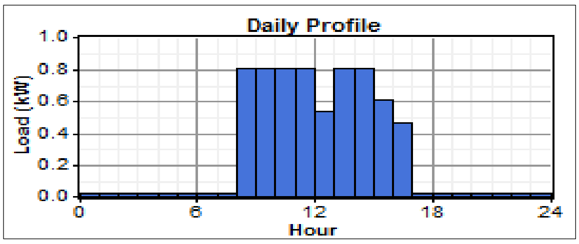

**Fig. 3** Load profile of the primary school on a 24-hour imeline basis for summer season

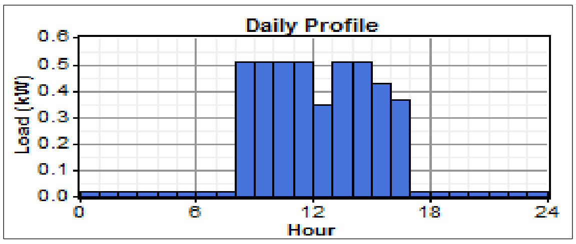

**Fig. 4** Load profile of the primary school on a 24-hour timeline basis for winter season

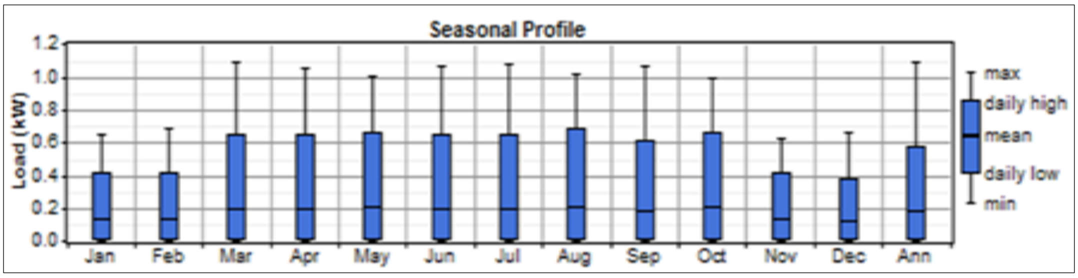

**Fig. 5** The seasonal and annual load profile of the school

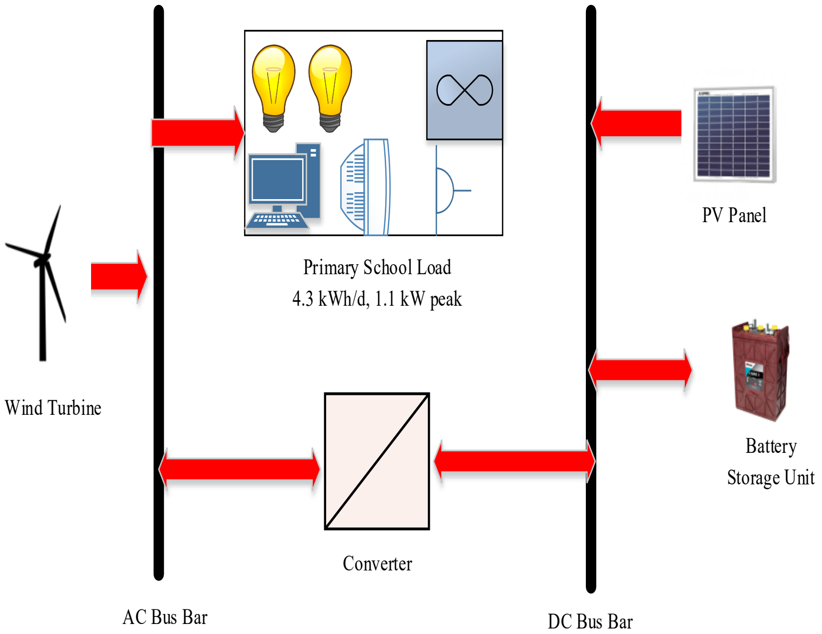

**Fig. 6** Architecture and model of HRES for rural primary school

## 3. Parametric Selections for the system design

The derating factor that accounts for the reduction in PV output over the timespan of usage for the selected village was set as 90 per cent, with a ground reflectance of 20 per cent, and a slope angle of 22.8 degrees. Also, the temperature coefficients of power in per cent per degree centigrade (%/˚C) of -0.5, a nominal operating cell temperature of 47˚C, and an efficiency of 13 per cent at standard test conditions were assumed. For an economic evaluation, the value of per kW capital cost of the PV module and replacement cost was USD $1330, for the project lifetime of 25 years.

A 3-blade upwind turbine with a rated output power of 2.5 kW was considered at a hub height of 24m. The capital cost of a wind turbine has been assumed to be USD $1500, with a replacement cost of USD $1000.

A Trojan L16P deep-cycle battery was considered with a nominal capacity and voltage of 2.34 (kWh) and 6 V respectively and a maximum capacity of 390 (Ah). The capacity ratio of the storage unit is 0.267 with a rate constant (1/hr) of 1.65. Also, the round-trip efficiency, which determines the fraction of the energy that can be restored, is 85 per cent. It was assumed that the properties of the storage system are unaffected by external factors such as temperature. However, the operation of the battery was set so that the state of charge (SoC) level would never to be drawn below 30 per cent. The capital cost and replacement cost of the battery at approximately every ten years were determined as USD $170 and USD $130 respectively.

As most solid-state converters are less efficient at low load due to standing losses, a converter has been introduced in the HRES model. The capital cost per kW and the replacement cost at the end of the fifteenth year was USD $300 and USD $300, for the project.

## 4. Results and Discussion

The analysis of the modelled HRES can be broadly classified into two phases, namely a technical and an economic assessment. The technical aspects discussed in this paper is based on the technical specifications as per the IEC/TS 62257 standards for rural electrification (Louie, 2018). The technical standards specify recommendations and microgrid system designs for hybrid systems with respect to rural electrifications. The economic aspects of the case study discuss the cost analysis of an annualized and net present cost of the system on the basis of the system components and resources selected.

### *Technical Analysis*

The technical analysis of the system is based on the energy management layout as specified in the IEC/TS 62257 standard for rural locations and communities, where the balancing of the load as per the user's requirements are given priority. In order to achieve the goal of energy management for balancing the electrical load of the school, as stated before, the HRES was modelled for an average of 4.3 kWh/day with a peak load demand of 1.1 kW. The model has been configured to support the necessary energy requirement.

The reliability of a system based on a 100 per cent renewable fraction (RF), is an important aspect of any microgrid system, considering the intermittent nature of the renewable energy sources. It, therefore, necessitates the purpose to analyze the system for the AC primary load consumption, which is 1519 kWh/yr with an unmet load of 2.5 percent kWh/yr, as seen in Fig. 7 for the energy system designed for the school. The preceding technical analysis of the microgrid is followed by the capacity utilization of the resources for the off-grid system as per IEC/TS 62257. The share of average electricity production of the system constitutes 59 per cent PV power and 41 per cent wind energy power, as shown in Fig. 8. Also, Fig. 8 answers the need for considering an HRES system for an off-grid location considering the system reliability aspects wherein the present case a deficit of solar energy in winters was seen to be nullified by the presence of an additional wind energy source. The modelling and parametric selection thereby indicate that the selected HRES is suitable for the geographical conditions of the selected rural site for the microgrid installation. Consecutively, the simulation results reveal the hours of operation of the PV module and the wind turbine as 4365 hr/yr and 5521 hr/yr respectively.

The technical investigation is further followed by the analysis of the electrical properties of the battery storage unit. The system has been modelled with a battery string size of 4 and a bus voltage of 24 V. The nominal capacity of the battery is 8.6 kWh with a usable nominal capacity of 6 kWh. The lifetime throughput of the battery, defined as the yearly cycling of the energy, is 4300 kWh with an annual throughput of 426 kWh/yr. However, the system losses for the battery unit accounts for 67 kWh/yr with the SoC of the battery unit has been set not to draw below 30 percent of the maximum battery storage limit. This accounts for a healthy state of the battery storage unit for a major portion of the year, accounting for 90 per cent per year with the SoC level reaching the set criteria for less than 5 per cent for an entire year, as seen in Fig. 9.

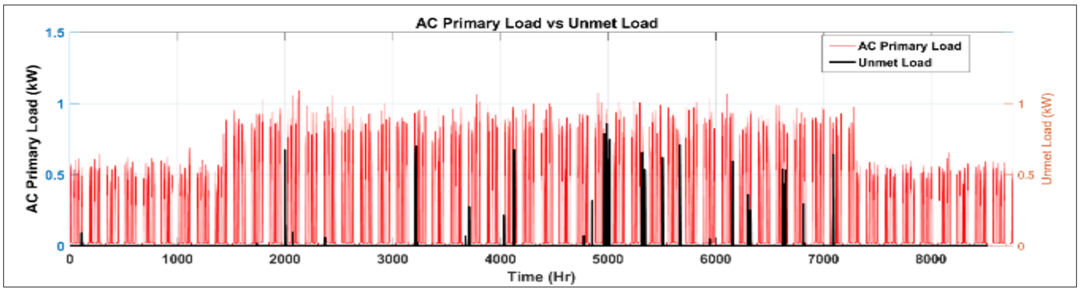

**Fig. 7** Analysis of comparison of AC Primary load and unmet load

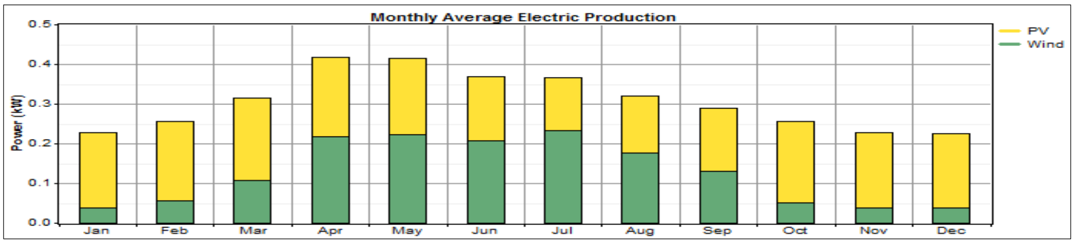

**Fig. 8** Monthly average electrical production from the PV/wind generation sources

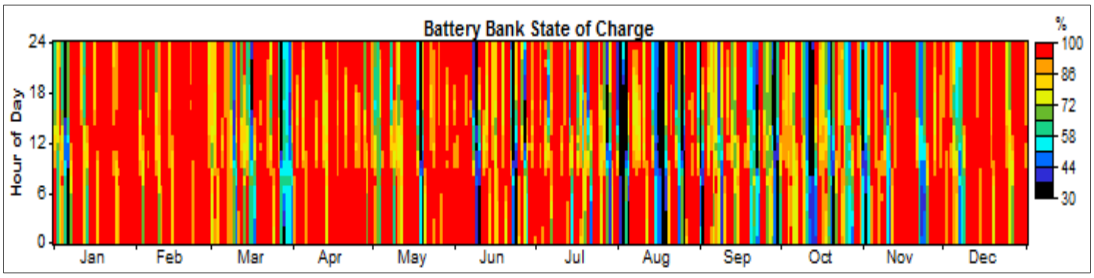

**Fig. 9** D-Map of the SoC of the battery storage system

*Economic Analysis*

The importance of economic analysis lies in understanding the aspects of the economic feasibility of the microgrid infrastructure, enabling it to be implemented on a practical level. Also, it could be a step forward to attract investors, utilities and the nodal agencies for setting up an off-grid electrification infrastructure where the centralized grid extension fails. The economics of any microgrid system is determined by the system's overall net present cost (NPC), which is determined by the difference of the present existing value of all the costs incurred over lifetime, and the value of the salvage revenue earned over the project lifetime of 25 years, or cost of energy (COE), given by average cost per kWh of useful electricity generated by the system and the operating cost (OC), which is the summation of the operation and maintenance cost, fuel cost and replacement costs minus the salvage cost. In the present analysis the NPC, COE, and OC are USD $4304, USD $0.22 and USD $39 respectively for an initial capital cost of USD $3810.

The cost incurred for the system can be summarized on aspects of net present cost of the components for the project lifetime, as seen in Fig. 10, and the share of the net present cost of the parameters selected for the model, based on cost type (capital cost, replacement cost, operating cost, and salvage value), as can be seen in Fig. 11. It can be seen that the PV and the wind turbine selected for the model require a capital investment of USD $1330 and USD $1500. The selected battery storage system and the converter used for the purpose of the system modelling show an impact on the overall economics of the project lifetime, with replacement costs in addition to the capital investments. The profit if any for the system adheres to the salvage value of the system components calculated at the end of the project lifetime.

Another aspect of analyzing the system is based on the annualized based cost summary of the HRES. An annualized based cost summary depicts a yearly based cost estimation for the economics of the system parameters involved in the project. This enables a relatively simple understanding of the economic analytics of the project involved.

An annual cost summary of the system parameters featuring the microgrid can be seen in Fig. 12, with the type of cash flow involved annually (capital cost, replacement cost, operating cost, fuel cost, and salvage value) for the system illustrated in Fig. 13.

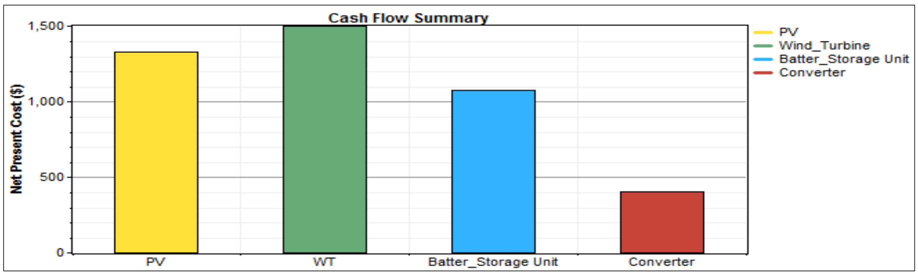

**Fig. 10** Net Present Cost of the system by component type

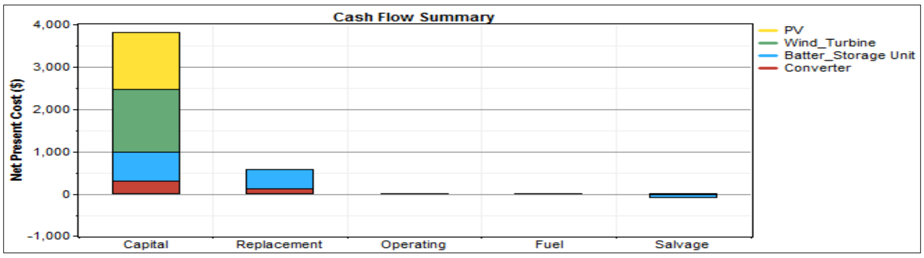

**Fig. 11** Net Present Cost of a system based on cost type

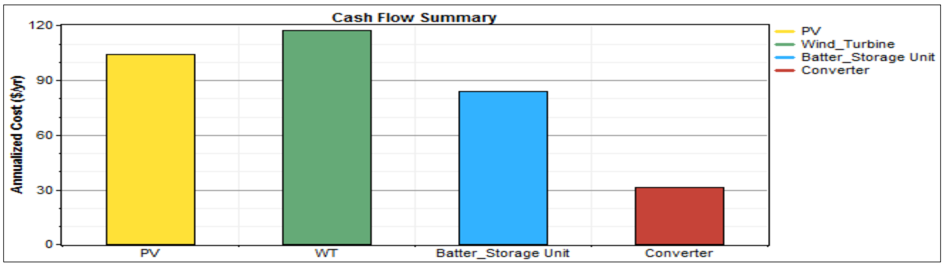

**Fig. 12** The annualized cost of the system based on component cost

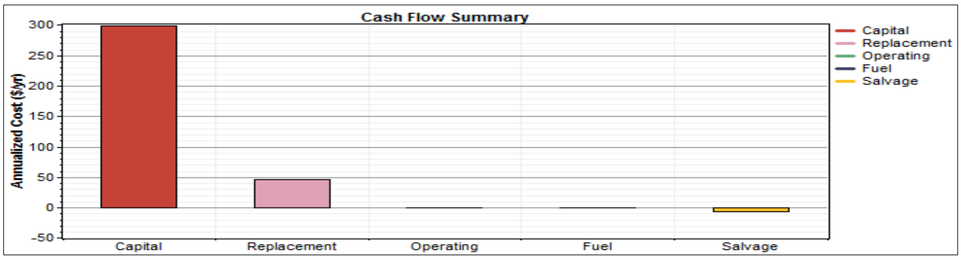

**Fig. 13** Annualized summary of the system based on cost type

## 5. Aspects for further consideration to enable such systems

The previous section of the research focused on designing a sustainable microgrid system and evaluating the techno-economic feasibility thereof for an educational institution in a rural setting. However, in order to achieve an uninterrupted electricity service and boost the deployments of microgrids for the proper functioning of rural schools, the following needs to be considered:

- *Encourage private sector investment:* The issues pertaining to the lack of finances and a high CAPEX of the microgrids create challenges, which require private sector investments for developing rural education infrastructures. Strategies may include yearly tax exemptions for private organizations involved in addressing the energy-education nexus, tax incentives on microgrid equipment, and other innovative business/subsidy models.
- *Participation of different Ministries and other government departments:* An alliance of various ministries of the government bodies for any country can be vital for improving the value proposition of microgrids in rural schools and accelerate its further deployments.
- *Awareness of energy consumption and management:* Awareness among the students and the teachers of the primary schools in terms of energy consumption patterns and the need for a paradigm shift to sustainable energy alternatives, can support towards improving the lives of the children in a long run.
- *Policies for energy efficient schemes*: India's LED bulb program, 'The UJALA Programme', has become a world-class success story by providing subsidized energy efficient bulbs to the economically challenged households in the rural areas (Nahar, Hasib, George, & Mukherjee, 2018). To achieve intensive electrification for the rural primary education institutions, a competitive business model like the 'UJALA Scheme' needs to be developed.
- *Establish an audit scheme for microgrids supporting rural primary schools:* An average annual load growth due to an increase in class size and a number of appliances, requires a regular assessment on a 5-year interval basis, to evaluate the quality indicators for reliable and uninterrupted electricity supply to the schools. Further, a 5-year audit scheme would also determine the cash flow analysis, thereby recognizing the specific areas of improvisation for the system's overall finances and decisions. Table 2 demonstrates a sample of a 5-year audit scheme for the primary village school considered for the case study in the research.

**Table 2**

Tabulation of a 5-year cash flow assessment of the microgrid for the rural school

| Component | Cost Category | Cash Flow every 5 Year | | | | | | Total Cost |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 25 | |
| PV | Capital | -1,330 | 0 | 0 | 0 | 0 | 0 | -1,330 |
| | Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Salvage | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Operating | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | -1,330 | 0 | 0 | 0 | 0 | 0 | -1,330 |
| Wind-Turbine | Capital | -1,500 | 0 | 0 | 0 | 0 | 0 | -1,500 |
| | Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Salvage | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Operating | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | -1,500 | 0 | 0 | 0 | 0 | 0 | -1,500 |
| Battery Storage Unit | Capital | -680 | 0 | 0 | 0 | 0 | 0 | -680 |
| | Replacement | 0 | 0 | -520 | 0 | -520 | 0 | -1,040 |
| | Salvage | 0 | 0 | 0 | 0 | 0 | 260 | 260 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Operating | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | -680 | 0 | -520 | 0 | -520 | 260 | -1,460 |
| Converter | Capital | -300 | 0 | 0 | 0 | 0 | 0 | -300 |
| | Replacement | 0 | 0 | 0 | -300 | 0 | 0 | -300 |
| | Salvage | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| | Operating | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | -300 | 0 | 0 | -300 | 0 | 100 | -500 |
| Overall System | Capital | -3,810 | 0 | 0 | 0 | 0 | 0 | -3,810 |
| | Replacement | 0 | 0 | -520 | -300 | -520 | 0 | -1,340 |
| | Salvage | 0 | 0 | 0 | 0 | 0 | 360 | 360 |
| | Operating | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | -3,810 | 0 | -520 | -300 | -520 | 360 | -4,790 |

## 6. Conclusion

The research highlights the accord for the electricity-education at rural educational institutions as a fundamental task for the achievement of the SDGs. The paper uses a technical approach to address the social issues of similar characteristics underlying in the remote villages of developing countries where centralized grid extension is unlikely for the provision of electricity to schools. The research successfully demonstrates a minimum energy requirement of 4.3 kWh/day for a rural primary education facility to balance the load requirement in the form of basic lighting, cooling, and other ICT devices. The economic analysis of the system model for a 25-year project lifetime indicates the net present cost and cost of energy as USD $ 4304 and USD $0.22/kWh respectively.

With the present scenario of the absence of encouraging microgrid policies in developing countries like India, the study of the load estimation for the school in terms of technical aspects, followed by a 5-year cash flow economic assessment, and other considerations, are outlined for the successful deployment of microgrids; as a potential means to address the SDGs.

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